Unsupervised Wind Turbine Anomaly Detection
A Weighted Cepstral Distance Application

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1 Introduction

The (power) cepstrum of a signal is a technique stemming from the field of *homomorphic signal processing* [5]. In this presentation, we use the weighted cepstral distance [1, 2, 4] to do unsupervised anomaly detection in wind turbines.

2 SISO cepstrum

The *power cepstrum coefficients* of a univariate signal $y(k)$, with k denoting time, are defined as [5]

$$c_y(k) = \mathscr{F}^{-1}(\log \Phi_y(\mathrm{e}^{i\omega})), \tag{1}$$

with $\Phi_y(\mathrm{e}^{i\omega}) = \left|Y(\mathrm{e}^{i\omega})\right|^2$ the *power spectrum* of the signal (and $Y(\mathrm{e}^{i\omega})$ the *Fourier transform* of the signal), and $\mathscr{F}^{-1}$ denoting the *inverse Fourier transform* operator.

A signal from a stochastic system, given in z-domain as

$$Y(z) = \frac{b(z)}{a(z)} U(z), \tag{2}$$

with $U(z)$ describing white noise, $a(z)$ the pole polynomial with the poles α_i as roots and $b(z)$ the pole polynomial with the poles β_i as roots, has cepstrum coefficients

$$c_y(k) = \sum_{j=1}^{p} \frac{\alpha_j^{|k|}}{|k|} - \sum_{j=1}^{q} \frac{\beta_j^{|k|}}{|k|}, \quad \forall k \neq 0. \tag{3}$$

The cepstrum is a characteristic of the dynamics of the generative system of the time series. A distance measure can be defined [1, 2, 4] on the cepstral coefficients as

$$d_c((y_1,u_1),(y_2,u_2)) = \sum_{k=0}^{\infty} k((c_{y_1} - c_{u_1}) - (c_{y_2} - c_{u_2}))^2, \tag{4}$$

with (y_1,u_1) and (y_2,u_2) the output/input-signal pairs of the respective systems. This distance measure can be interpreted in terms of model parameters and subspace angles between the output spaces of the systems.

An extension of the power cepstrum to multiple input multiple output (MIMO) systems was presented in [3]. However, an extension of the distance measure above to this case proves to be difficult, theoretically. We will focus on the details of why this is so in the presentation, and corroborate our results with an application on wind turbine anomaly detection.

3 Wind Turbine Anomaly Detection

Wind turbines have several built-in sensors, which are governed by a supervisory control and data acquisition (SCADA) system. In this presentation, we use open-source SCADA data from EDF [6], and focus on the topic of anomaly detection. We present an unsupervised anomaly detection method.

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